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Oil and the U.S. Macroeconomy:
An Update and a Simple Forecasting Exercise

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Abstract
Recently, some analysts and economists had warned that the U.S. economy faces a much higher risk of falling into a recession should the price of oil rise to $100 per barrel or more. In February 2008, spot crude oil prices closed above $100 per barrel for the first time ever, and they have since climbed even further. Meanwhile, according to some surveys of economists, there is a high probability that a recession in the United States began in late 2007 or early 2008. Although the findings in this paper are consistent with the view that the U.S. economy has become much less sensitive to large changes in oil prices, a simple forecasting exercise reveals that a permanent increase in the price of crude oil to $150-per barrel-by the end of 2008 would have a significant negative effect on the growth rate of real GDP in the short run. However, the exercise also predicts such an increase in oil prices would have minimal effect on future inflation.

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In December 2001, the spot price of West Texas Intermediate (WTI) crude oil averaged $19.33 per barrel. Shortly thereafter, oil prices started to trend higher. After a brief decline from $74 per barrel in July 2006 to about $55 per barrel in January 2007, oil prices then resumed their upward trajectory. They surpassed $90 per barrel in October 2007. During the run-up in crude oil prices over the past few years, some economists and energy analysts correctly expected the price of crude oil to eventually rise to $100 per barrel or more, and crude oil prices eventually closed above $100 per barrel on Feb. 19 for the first time ever.[1] Some of these analysts also predicted that $100 per barrel crude oil would cause the U.S. economy to fall into a recession.

Conventional economic theory suggests that higher oil prices lead to a reduced rate of growth in aggregate economic activity in the short run.[2] Empirically, the largest adverse effects have stemmed from the oil shocks that occurred prior to 1983. Consistent with this view, this article finds that the growth rates of several key economic indicators, and their measured volatility, are distinctly different before and after the six major oil shocks that have occurred since 1973. However, non-oil factors also appear to be significant explanatory factors in the performance of the economy before and after 1973. Using an augmented model proposed by Hamilton (2003), this article will show that a permanent increase in the spot price of crude oil to either $100 or $150 per barrel would cause a substantial slowing in real GDP growth and its major components relative to a baseline forecast without oil prices. Given the relatively weak growth projected over the first half of 2008, this result could be significant. However, such an increase in oil prices

[1] See Greenspan (2007), King and Chazan (2007), and Verleger (2007).
[2] Using a static aggregate demand—aggregate supply model, an increase in energy prices causes the aggregate supply curve to shift up along a stationary aggregate demand curve. Over time, though, the economy returns to its long-run level of potential output.

is shown to have little or no effect on future inflation rates relative to a baseline forecast without oil prices.

OIL AND MACROECONOMIC ACTIVITY: THE THEORY AND EVIDENCE

Oil shocks tend to be viewed with alarm by forecasters, macroeconomists, financial market participants, and public policymakers.[3] An oil price shock is typically a large, unexpected increase in the relative price of energy that adversely affects the economic decisions of firms and households.[4] These effects are both direct and indirect (second-order effects) and vary in magnitude across time. To begin with, higher crude oil prices directly raise the prices of petroleum-based products such as gasoline or diesel fuel. Because crude oil is an important energy source for most industrialized or industrializing countries, there can also be important pass-through (secondary) effects to the prices of non-energy goods and services. These include fuel surcharges implemented by those in the transportation services industry (e.g., FedEx or UPS).

At the same time, the duration of these economic effects varies with its permanence and with the passage of time. In the short-run, the price elasticities of the supply and demand for oil is likely very low because firms and consumers may find it difficult to change their consumption immediately and new sources of oil or alternative sources of energy are not immediately available. Over the longer term, these price elasticities will likely be larger. Higher prices spur producers to seek out new sources of crude oil, but they also provide important incentives to increase the production of alternative energy sources, such as ethanol or bio-diesel. Higher oil prices also prompt users to conserve energy.

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[3] See Bernanke (2004).

[4] See Brown, Yucel, and Thompson (2004), Jones, Leiby, and Paik (2004), and Hamilton (2005) for a survey of oil-macroeconomy literature.

Most oil price shocks are the result of reductions in supply arising from wars, embargoes, or geopolitical uncertainty tied to developments in important oil-producing regions. However, the latest rise in oil prices appears to be stem importantly from fast-growing Asian countries. Regardless, as seen in Figure 1, nearly all post-World War II recessions in the United States were preceded by, or accompanied by, an increase in oil prices. The behavior of oil prices, though, was decidedly different before the 1970s.[5] According to Hamilton (1985), changes in U.S. crude oil prices prior to the 1970s were largely the result of exogenous shocks. Especially important were decisions by the Texas Railroad Commission, a state regulatory agency that actively sought to control the production of Texas crude oil. As a result there was remarkable stability in domestic oil prices during this period. After the 1970s, a period of rising political instability in the Middle East when the Organization for Petroleum Exporting Countries (OPEC) was formed, oil prices became much more volatile compared with the earlier period. This increased volatility, at first glance, appears to have had important economic consequences. For example, in percentage terms, oil price increases that preceded the recessions after 1973 were considerably larger than those before 1973. Figure 1 also suggests that oil price volatility has increased since the mid 1980s.[6]

"The new energy regime," as the 1970s was sometimes called, spawned a literature that sought to quantify the effects of higher energy prices on output, inflation, and employment.[7] Rasche and Tatom (1977a, 1977b) and Baily (1981) were among the first to study the transmission mechanism between oil price changes and real GDP

[5] Hamilton (2005) argues that the size of the oil price shock can be measured in either real or nominal terms, but most researchers prefer to use nominal prices.
[6] Though not shown, this is in contrast with the reduced volatility of aggregate output and inflation that is often termed "The Great Moderation."
[7] This section has been adapted from Guo and Kliesen (2005).

growth. Subsequently, Hamilton (1983), among many others, documented a negative and significant relation between oil price changes and future GDP growth. But as Hooker (1996) showed, this result breaks down in the data after 1986. In 1986, recall, there was a sharp, unexpected decline in oil prices. In Hamilton's original linear specification, he implicitly assumed that oil shocks had a symmetric effect on economic activity: Increases (decreases) in oil prices reduce (raise) future GDP growth. This specification is consistent with the transmission channel cited in the early studies mentioned above and those of a more recent vintage, such as Wei (2003). However, the effect can be also *asymmetric*. To account for nonlinearities in the data, Hamilton (2003) proposed a net oil price increase variable. In this specification, oil price increases influence economic activity, such as the growth of real GDP, but oil price decreases do not (more on this variable later).

An oil price increase may lower future GDP growth through other channels. In particular, sharp oil price changes—either increases or decreases—affect macroeconomic activity for at least two reasons. First, they raise uncertainty about future oil prices and thus cause delays in business investment (e.g., Bernanke [1983] and Pindyck [1991]). Guo and Kliesen (2005), for example, find that increased oil volatility over the period from 1984 to 2004 had a significant and adverse effect on key measures of U.S. macroeconomic activity, such as business capital spending. Second, oil price changes induce resource reallocation from more adversely affected sectors to less adversely affected sectors, and such reallocation is costly (e.g., Lilien [1982], Davis and Haltiwanger [2001], and Lee and Ni [2002]).

The link between oil price changes and economic activity is complicated by other factors, such as the physical demand for the product, which to some degree is influenced by economic growth, and the influence of domestic monetary policymakers. According to Barsky and Kilian (2004), the linkage between higher oil prices and weaker economic growth is complicated by the endogeneity of oil prices. This view holds that demand shocks, rather than supply shocks have been the dominant factors explaining higher oil prices. In a subsequent paper, Kilian (2007) asserts that precautionary demand shocks, which he defines as expectations about future oil supplies, have also been important. Another view, expressed by Bernanke, Gertler, and Watson (1997), holds that the dominant cause of recessions was not due to the sharp rise in oil prices but rather to the endogenous response of monetary policymakers.[8] Other studies examining the interaction between monetary policy and oil price shocks include Leduc and Sill (2004) and Hamilton and Herrera (2004).

OIL AND THE MACROECONOMY SINCE 2001

Table 1 lists the change in several major economic series from December 2001 to December 2007. The former period corresponds with the date chosen by the National Bureau of Economic Research Business Cycle Dating Committee to be the first month of the current business expansion. [NOTE: For the quarterly series in the table, such as the long-term forecast for real GDP and labor productivity growth, the initial period is the fourth quarter of 2001 and the final period is the third quarter of 2007.] From December 2001 to December 2007, the nominal price of crude oil on the spot market (WTI) has risen by 375 percent, while the nominal composite price paid by refiners (refiners

[8] They argue that this result is strongest during the Volcker era.

acquisition cost, or RAC) has increased by about 425 percent.[9] In real terms, the RAC price has increased by 365 percent.

Table 1 shows that while total PCE inflation has increased by 2 percentage points over this period, the core measure (excluding food and energy prices) has been virtually unchanged and the yield on the 10-year U.S. Treasury security has declined by nearly 1 percentage point. In response, Federal Reserve policymakers, increased their nominal federal funds target rate by nearly 275 basis points (from about 1.75 percent to about 4.5 percent), and their real federal funds target rate by a little more than 50 basis points.[10] The modest tilt toward a more restrictive monetary policy may help explain why both measures of long-term inflation expectations were little changed (on average) over this period. Despite sharply higher oil prices over the past six years, long-term forecasts for labor productivity and real GDP growth have increased slightly.

Estimates of the short-run macroeconomic effects of higher oil prices on real GDP growth vary. According to a recent survey of several macroeconomic models reported by Huntington (2005), a $10 per barrel increase in the price of oil is expected to reduce output by about 0.25 percentage points in the first year and by roughly 0.5 percentage points in the second year (relative to a baseline forecast).[11] A study published by the International Monetary Fund in December 2000 showed that a permanent $5 increased in the price of oil would reduce world real GDP growth by roughly 0.25 percentage points per year over the first four years; the affect on U.S. real GDP growth over the same

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[9] The composite cost of crude oil is a weighted average of prices paid by refiners for domestically produced and imported crude oil, including transportation and other fees paid by the refiner. The RAC is published by the U.S. Department of Energy.

[10] The FOMC reduced its intended federal funds target rate on Dec. 11, 2007, by 25 basis points to 4.25 percent; by an additional 125 basis points in January 2008; and by an additional 75 basis points in March 2008.

[11] These models assume a constant price elasticity in the short-term because of the limited ability to substitute away from oil as an energy source.

period was slightly larger than 0.3 percentage points per year.[12] Similar results were found for models used by the Federal Reserve (MULTIMOD), the Organisation for Economic Cooperation and Development (INTERLINK), and the Brookings Institution (McKibbin and Sachs).

Economic Activity Before and After Oil Shocks

Dating oil price shocks tends to be a subjective endeavor. Blanchard and Gali (2007) define an oil shock episode as a cumulative (log) change in the price of oil of at least 50 percent, sustained for four quarters. This definition gives them four episodes: 1973, 1979, 1999, and 2002. Figure 2 shows an alternative method: A sustained <u>positive</u> increase in the <u>year-to-year</u> percentage change in the real spot price of WTI. For example, in July 1973, real WTI prices were 5.1 percent less than a year earlier. However, oil prices rose nearly 20 percent in August 1973, causing real WTI prices to be 13.9 percent higher from a year earlier. The 12-month percent change in real WTI remained positive—except for a small 0.5 percent decline in January 1975—until September 1975 (26 months).[13] The following month, October 1975, oil prices had fallen 6.6 percent below their year-earlier levels. Negative year-to-year percent changes are registered as zeroes in the chart. By this methodology, the oil shock would have occurred in August 1973 (third quarter of 1973).

This method produces six oil shock dates: 1973, 1979, 1989, 1995,1999, and 2002. These are shown in Figure 2.[14] To see how economic performance around these six major oil shocks has changed over time, Table 2 shows economic volatility for several

[12] The IMF used the average price of U.K. Brent, Dubai, and WTI. In November 2000, this reference price averaged about $32 per barrel according to the IMF.
[13] The cumulative (12-month) percent change over this period was more than 1,800 percent, but that is not an important consideration in this framework.
[14] Four of the oil shock dates in Figure 2 match Blanchard's and Gali's dates: 1973, 1979, 1999, and 2002.

major series four quarters before and after these episodes. The first five series listed in Table 2 are major measures of output and expenditures. The next four series measure CPI- and PCE-based overall inflation and inflation excluding food and energy prices (core inflation). The next three series measure labor markets and consumer confidence, and the final three series measure short- and long-term interest rates and the real spot price of WTI crude oil. Economic volatility was generally quite high during the four quarters immediately before and after the first two oil shocks (1973 and 1979). For example, the standard deviation of real GDP growth during the four quarters before the 1979 oil shock (1979:Q2) was nearly 7 percentage points; output volatility fell modestly in the immediate aftermath of the oil shock (4.9 percentage points) but still remained quite high. By contrast, the volatility of GDP prior to the latest oil shock dropped to less than 2 percentage points. In general, oil shocks cause outlays for capital goods to be much more volatile than household expenditures on goods and services.

Table 2 also reveals that economic volatility appears to have increased in the period both immediately before and after the past two oil shocks (1999 and 2002). For example, volatility of overall PCE and CPI inflation has increased, as has the volatility of core CPI inflation. One notable exception is the volatility of core PCE inflation. Although the increased volatility prior to the 2002 oil price shock was the largest since the 1979 oil shock, the volatility of core PCE inflation in the four quarters following the shock has been quite low (0.29 percentage points). Figure 3 puts this increased economic volatility in a different light. In the Figure 3, 20-quarter rolling standard deviations of the one-quarter compound annual rates of growth for real GDP and CPI and core CPI inflation are plotted. In addition, vertical lines marking the 1973, 1979, 1989, 1999, and 2002 oil shocks are shown.

Inflation volatilities tended to rise sharply after the 1973 and 1979 shocks, but less so after the latter shocks. More recently, the volatility of CPI inflation has accelerated beginning around 2006, reaching its highest level in the fourth quarter of 2007 since 1991. Similarly, the volatility of core CPI inflation appears to have risen, though the acceleration preceded the 2002 shock. However, core inflation volatility remains quite low from an historical perspective. Volatility of real GDP growth also tends to increase immediately after oil shocks. The notable exception is the 2002 episode. Since then, the volatility of real GDP growth has actually declined.

The Effects of Oil Price Changes on Output and Inflation Since 1970

To get a rough idea of the potential effects of higher oil prices on real GDP growth and inflation, one can employ the simple model used by Hamilton (2003):

$$\Delta \ln(y_t) = \alpha_t + \sum_{i=1}^{4} [\beta_i \Delta \ln(y_{t-i}) + \delta_i \Delta \ln(x_{t-i})] + e_t \tag{1}$$

Hamilton originally used the log change in real GDP (not an annual rate), y_t. In this analysis, though, y_t will be a measure of the log change in real GDP at an annual rate. The oil price change, x_t, is the price of crude oil transformed according to Hamilton (2003).[15] Hamilton showed that an asymmetric measure of oil prices helps explain real GDP growth. He also showed that the sum of the coefficients on the lagged values of the net oil price (NOP) measure were highly significant, even though some of the individual

[15] This analysis uses the producer price index for crude petroleum, the same series used by Hamilton. The quarterly value is not the average of the monthly observations (e.g., January, February, and March), but instead it is the last month of the quarter (March, June, September, December).

coefficients were not. Hamilton's measure of the NOP is constructed in the following way: The current-quarter percentage difference (taken to be the observation in the last month of the quarter; for example, March, June, September, December) is compared with the maximum price over the past 12 quarters. If the percentage difference is positive, that observation is used, but if the percentage difference is negative, that month's observation is set to zero. Thus, in the Hamilton framework, only energy price increases matter; energy price decreases do not matter.

Table 3 reports regression results of the above equation and three alternative specifications. The sample period is 1970:Q1 to 2007:Q4. The analysis begins in 1970:Q1 because, as is evident from Figure 1, there was relatively very little volatility in oil prices prior to 1970. Accordingly, a very large percentage of observations for the Hamilton net oil price variable are zeroes before 1970. Second, all of the major oil price shocks have occurred since 1973.

Regression (1) in Table 3 reports results from a model that predicts future real GDP growth using lagged growth rates. Although this simple AR(4) model is commonly used to predict future GDP growth, the adjusted R^2 is quite low, 0.06. Regression (2) is Hamilton's model cited above. Adding the NOP variable doubles the explanatory power of the model, as the adjusted R^2 rises to 0.12. Interestingly, adding the NOP variable renders insignificant the first and second lags of real GDP growth, which were significant in (1).

Regressions (3) and (4) extend Hamilton's analysis by adding the Federal Reserve Bank of Chicago's National Activity Index, z_t:

$$\Delta \ln(y_t) = \alpha_t + \sum_{i=1}^{4}[\beta_i \Delta \ln(y_{t-i}) + \delta_i \Delta \ln(x_{t-i})] + \sum_{i=0}^{1} \gamma_i z_{t-i} + e_t \qquad (2)$$

The Chicago Fed National Activity Index (CFNAI) is the first principle component, or common factor, of 85 monthly indicators of real economic activity.[16] Much empirical research has shown that principle components can significantly improve the forecasting performance of major macroeconomic variables such as real GDP growth and inflation.[17] This result is reinforced in regressions (3) and (4) in Table 3. Adding the contemporaneous and lagged value of the CFNAI (z_t and z_{t-1}) to both the AR(4) model and Hamilton's equation cited above shows that the CFNAI is highly significant.[18] In addition, the first and second lags of NOP are now highly significant as well. As a result, the explanatory power of regressions (3) and (4) is significantly larger than for regressions (1) and (2).

A further extension of Hamilton's analysis can be seen in Table 4. In this case, the analysis examines whether the NOP variable helps to predict the growth of real GDP—and, separately, its major components—and inflation (log change) using four separate price measures. The inflation series are based on the overall price indexes measured by the consumer price index (CPI) and the personal consumption expenditures (PCE) price index (PCEPI), as well as their respective "core" measures, which exclude food and energy prices. The empirical results reported in Table 4 are based on equation (2) above. Hence, the GDP expenditure categories and price variables will become, separately, the y_t terms. Each row in Table 4 reports the F-test to determine the significance of the sum of the coefficients on oil prices. For example, in the first row y_t would be real GDP; in the second row y_t would be the growth of real personal consumption expenditures, and so

[16] See the "CFNAI Background Release" and Technical Report" on the Federal Reserve Bank of Chicago website (http://www.chicagofed.org/economic_research_and_data/cfnai.cfm).
[17] See Gavin and Kliesen (2008) and the references cited therein.
[18] The second, third, and fourth lags of CFNAI were dropped because they were not significant.

forth. For the reasons noted above, the analysis is based on the period from 1970:Q1 to 2007:Q4. In this case, though, Table 4 also reports results for three subperiods: 1970:Q1 to 1982:Q4; 1983:Q1 to 1994:Q4; and 1995:Q1 to 2007:Q3. The partition of the second and third period reflects, first, the period of the Great Moderation, which is generally conceded to have started in about 1983, and, second, the acceleration in trend productivity growth. The latter development is generally thought to have commenced around 1995.[19]

Effects on Output

Table 4 reveals that energy price increases significantly help to predict real GDP growth and most of its components. However, the size of this effect varies across indicator and across time. Over the entire sample period the sum of the energy coefficients on real GDP growth was highly significant, though modest (-0.09).[20] The first row of Table 4 indicates that the oil price increases have had their largest effect on real GDP growth over the final period (-0.13). The effects of energy price increases on real GDP growth were much smaller in the second period (-0.06), which is sometimes called The Great Inflation. Over the proceeding period, though, the effect of energy prices on real GDP growth, while still significant, was small (-0.005).

Table 4 reveals some other interesting findings. First, during the period of the Great Inflation, oil price increases had their largest (negative) effects on real residential fixed investment and imports; however, the effect on real consumer spending was relatively small during this period. Second, oil price increases generally had their smallest effect on the components of real GDP from 1983 to 1994. The notable exception was real

[19] See Anderson and Kliesen (2006).

[20] Excluding the CFNAI, the sum of the coefficients increases (in absolute terms) to -0.19.

consumer spending. Moreover, in the cases of real fixed investment in business equipment and software and real imports, the sign not only changed, but the significance of oil price increases disappeared. Third, since 1995, the sensitivity of real E&S investment has increased significantly. In fact, the coefficient is about equal in magnitude to the second period, but the sign is now changed. In addition, higher oil prices now help to predict business investment in structures. However, this change could reflect the fact that the share of nominal fixed investment in drilling and mining activity as a percent of nominal nonresidential fixed investment has increased from about 1.75 percent in 1995 to 8 percent in 2007. Finally, although the effect of oil price increases on real PCE since 1995 has diminished somewhat compared with the 1983-94 period (from -0.19 to -0.11), the sum of the coefficients are more significant compared with the earlier period.

Effects on Consumer Price Inflation

The last four rows of Table 4 report the results of equation (2) applied to the four price series mentioned above.[21] Since 1970, the sum of the coefficients on oil price increases, which have the expected positive sign and are highly significant, are essentially the same for both the total CPI and the total PCEPI (0.04). But whereas the sums of the coefficients on the core price indexes are also roughly equal to each other, the sums of the coefficients are larger, and even more significant, than for the total price measures. It appears that the latter effect stems from the Great Inflation period. Since 1983, the effects of higher oil prices on core inflation have been much more modest, and considerably

[21] A version of Table 3 was estimated for the PCEPI and core PCEPI series. That is, inflation was regressed on (i) four lags of inflation, (ii) four lags of Hamilton's NOP measure, and (iii) the contemporaneous and lagged value of the CFNAI. In results not published here, the adjusted R^2 for PCEPI inflation in (i) is 0.76. Adding the CFNAI increased the adjusted R^2 to 0.78. The adjusted R^2 for the AR(4) for core PCEPI is 0.82, and adding the CFNAI boosted the adjusted R^2 to 0.83. Adding Hamilton's NOP to the latter model raised adjusted R^2 to 0.86. These results are available on request.

smaller than those on the total price measures. The results in Table 4 provide some evidence for the FOMC's decision to place somewhat more emphasis on core PCEPI inflation during the run-up in oil prices over the past several years.

A Forecasting Experiment

Results from Tables 3 and 4 suggest that past oil price increases are statistically significant predictors of economic activity and inflation in the current quarter. This section will provide some evidence that Hamilton's NOP variable helps to forecast the growth of economic activity and inflation one quarter ahead. In this experiment, the baseline forecast uses an AR(4) model augmented with the CFNAI; this is a one-period ahead version of regression (3) in Table 3. To this restricted model, two energy price series are added separately: (1) the spot price of West Texas Intermediate and (2) the Producer Price Index for domestic crude petroleum (PPI). Each of these oil price series will be modified according to the Hamilton specification throughout the remainder of the paper. First, the restricted model (without energy) is estimated from 1970:Q1 to 2001:Q4. The model is estimated for each of the output and price series listed in Table 4. Next, one-step-ahead pseudo-out-of-sample forecasts (with and without energy) are computed from 2002:Q1 to 2007:Q4. Table 5 presents the root mean square errors (RMSE) from this forecasting exercise.

The value of any forecast to the practitioner or the policymaker is its accuracy. A standard test of forecast accuracy is the test proposed by Diebold and Mariano (1995, DM). However, as Clark and McCracken (2001, CM) point out, the DM test is not appropriate for nested models such as those used here. In Table 5, the null hypothesis is that the baseline forecasts (without NOP) have the same predictive power. Based on the CM test statistic, Table 5 shows that spot oil price increases can help improve the baseline, one-quarter-ahead forecast for the growth of real GDP, real PCE, and real imports. However, this is not the case for the PPI measure of oil prices. In all other series listed in Table 5, including the consumer price series, Hamilton's NOP variable does not improve the baseline forecast. In fact, Table 5 reveals that adding the WTI spot oil price increase to the price equations marginally improves the RMSE of the forecasts for overall CPI and PCE inflation. For example, adding the spot WTI to the CPI inflation forecasting equation reduces the RMSE from 2.03 (baseline) to 2.01. Notably, the RMSE for the PCEPI inflation forecasts are much smaller than they are for the CPI series.

For purposes of policymaking, however, what matters is alternative scenarios of economic growth and inflation over the near-term. Accordingly, the analysis is now extended to gauge the potential effects of higher oil prices on economic growth and inflation in 2008 and 2009. First, the model for each variable is estimated for the period from 1970:Q1 to 2007:Q4. Next, the model is used to forecast out-of-sample growth rates for the 2008:Q1 to 2009:Q4. The baseline forecast is the same AR(4) model augmented with the CFNAI.[22] To gauge the effects of higher oil prices, the baseline forecast is augmented with two separate scenarios for the spot price of WTI through 2009. Under the first scenario, the spot price of WTI averages \$100 per barrel for the four quarters of 2008 and remains at that level through 2009:Q4. Under the second scenario, the spot price of WTI increases from \$100 per barrel in the 2008:Q1 to \$150 per barrel in

[22] An AR(4) model is used to estimate the out-of-sample values for the CFNAI.

2009:Q1 and then remains at that level until the 2009:Q4.[23] Finally, these forecasts are compared with the forecasts released by the Federal Reserve Bank of Philadelphia's Survey of Professional Forecasters (SPF) on February 12, 2008. One drawback to the SPF is that the quarterly forecast horizon extends only to 2009:Q1.

Table 6 shows these out-of-sample forecasts for annual average growth rates in 2008 and 2009 for real GDP, real PCE, real business fixed Investment (BFI), and PCEPI and core PCEPI inflation.[24] As seen in Table 6, the baseline forecast for real GDP growth in 2008 (2.8 percent) is much more optimistic than the SPF forecast (1.9 percent). The baseline forecast with the $100 per barrel oil assumption is roughly equal to the SPF forecast in 2008, but the $150 per barrel oil assumption cuts this growth by 0.6 percentage points. For 2009, the difference in the growth of real GDP using $100 per barrel oil (3.6 percent) is even larger than the $150 per barrel oil scenario (2.2 percent). From this analysis, one can assume that an economy starting at 1 percent real GDP growth or less could plausibly end up with significantly negative growth rates in real GDP over the near term should the economy experience another large increase in oil prices. However, once oil prices stabilize, and the drag from higher oil prices ends, the model predicts modest above-trend growth. This is seen in the baseline forecast with $100 per barrel oil.

Forecasts for the remaining variables in Table 6 show that the baseline forecast with $100 per barrel oil is pretty close to the SPF forecast for 2008. The exception is real BFI, where higher oil prices are predicted to have their largest effects. Although the baseline forecast for real BFI in 2008 is substantially stronger than the SPF, higher oil

[23] Spot WTI is assumed to rise 10.75 percent per quarter from 2008:Q1 to 2009:Q1, reaching a level of $150.44 per barrel.
[24] The data series were last updated on Feb. 28, 2008.

prices dramatically weaken business capital spending. Although not shown, the $150 per barrel oil price briefly produces negative rates of real BFI growth in mid-2009. Perhaps the most interesting findings are those associated with the inflation forecasts. First, the baseline inflation forecasts for 2008 are essentially equal to the SPF forecast. Second, in the case of both the $100 and $150 per barrel oil scenarios, the model predicts lower average PCEPI inflation in 2008 and 2009. For core PCEPI inflation, higher crude oil prices do not produce forecasts of higher core inflation. This result, which is unusual, may reflect an enhanced degree of credibility that is being captured in the model's parameters. That is, the model may implicitly assume a Taylor-rule like response by policymakers to prevent higher oil prices from producing higher core inflation.

Conclusion

The analysis in this paper has used Hamilton's augmented model to gauge the effects of higher oil prices on real GDP growth, its major components, and four measures of inflation. The first major finding of the paper, consistent with Hamilton's result, is that oil matters. However, there are certain periods when it matters more or less. The second major finding is that the estimated negative effects of $100 per barrel oil on output growth are significant, but would wane by the end of 2008. However, an oil shock that raises crude oil prices to $150 per barrel by the first quarter of 2009 could produce a significant drag on growth rates of real GDP, real consumption expenditures, and, especially, real business fixed investment in 2008 and early 2009. This could be significant, given that actual real GDP growth was quite weak in the fourth quarter of 2007 and the forecasts for real GDP growth over the first half of 2008 have been marked down steadily and significantly over the past four months. But whereas higher oil prices are expected to produce a significant drag on near-term output and expenditure growth, they are not predicted to produce higher overall and core PCEPI inflation. This result, while perhaps unusual, may reflect a degree of credibility on the part of monetary policymakers. If so, it will be of utmost importance for policymakers to maintain this credibility in the face of future oil price shocks.

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Figure 1

Real and Nominal Change in Spot Oil Prices

Percent change from four quarters earlier

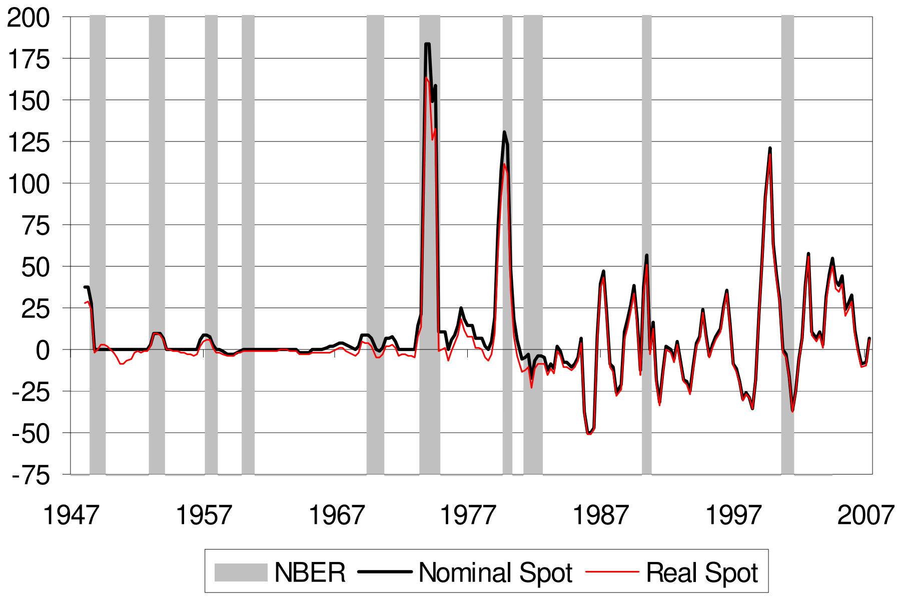
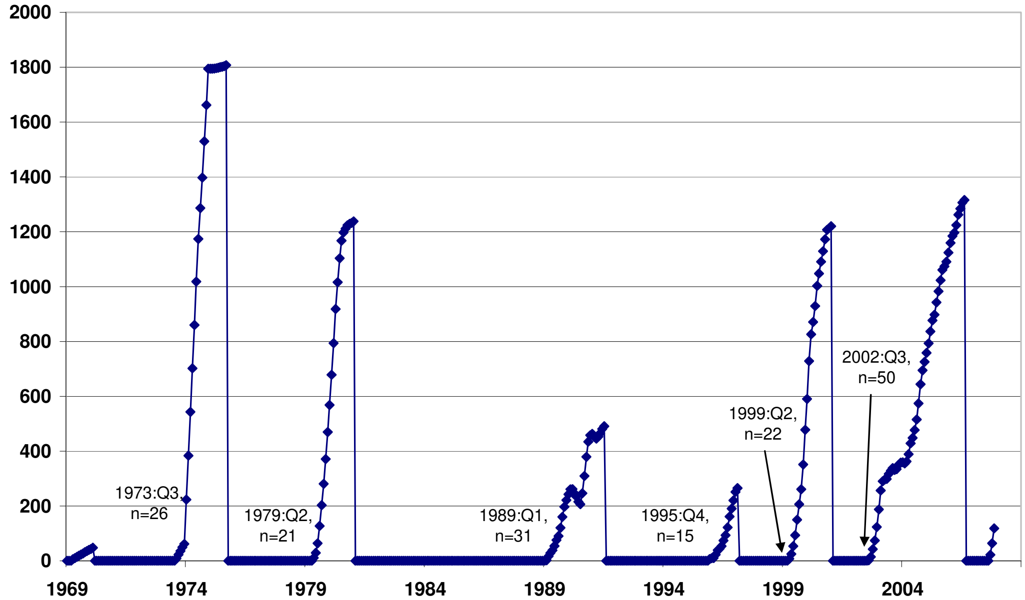


Figure 2

Dating Oil Price Shocks

Cumulative 12-Month Percent Changes in Real WTI Prices During Oil Shock Episodes (Zero Otherwise)



SOURCE: Author's calculations.

Figure 3

Economic Volatility: Real GDP and CPI Inflation

Rolling 20-Quarter Standard Deviations, percentage points

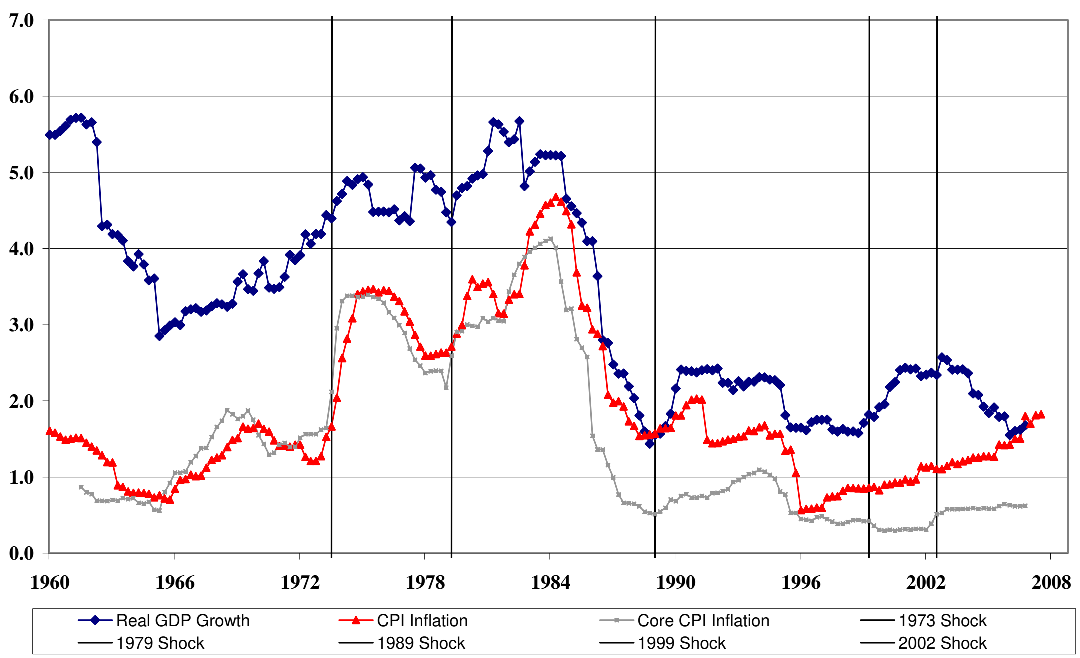


Table 1
Change in Economic Conditions Since December 2001

	Dec. 2001	Dec. 2007	Change
Real Oil Price (RAC)	$16.07	$74.67	364.5%
Nominal Oil Price (RAC)	$16.52	$86.40	423.0%
Nominal Spot Oil Price (WTI)	$19.33	$91.73	374.5%
10-Yr Treasury Yield (%)	5.09	4.10	-0.99
PCE Inflation (%)	1.46	3.47	2.02
Core PCE Inflation (%)	2.17	2.24	0.07
Nominal Fed Funds Rate (%)	1.82	4.32	2.50
Real Fed Funds Rate (%)	0.36	0.85	0.48
Corporate Profit Margin (quarterly)	7.75	11.61	3.85
Inflation Expectations			
Michigan, 1-Yr Median (%)	1.80	3.40	1.60
Michigan, 5- to 10-Yr Median (%)	3.00	3.10	0.10
SPF, 10-Year (Quarterly, %)	2.55	2.40	-0.15
Long-Term Forecasts (quarterly)			
Real GDP growth	2.50	2.75	0.25
Productivity growth	1.50	2.00	0.50

DEFINITIONS & NOTES:
Real oil price is the nominal price (refiners' acquisition cost of crude oil, composite) deflated by the PCE chain-type price index. PCE and core PCE inflation rates are 12-month percent changes. The real federal funds target rate is the nominal rate (monthly average of daily rates) less the PCE inflation rate. The yield on the 10-year Treasury is an average of daily rates. Long-term forecasts from the Philadelphia Fed's Survey of Professional Forecasters (SPF), which are published in February of each year. The forecast horizon is 10 years.

Table 2
Economic Volatility Four Quarters Before and After Six Oil Shock Episodes

	Averages, 4 Quarters BEFORE T=0						*Averages, 4 Quarters AFTER T=0*					
Episodes:	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
Real GDP	2.98	6.94	1.86	1.90	1.55	1.85	3.72	4.88	1.51	1.72	2.78	3.23
Real PCE	4.24	3.28	1.76	1.53	1.03	2.59	2.48	5.42	1.01	0.76	1.66	1.97
Real Business Fixed Invest.	7.15	13.06	3.66	8.88	4.46	3.82	3.18	13.47	7.39	1.59	6.38	8.06
Real Residential Fixed Invest.	15.85	12.60	5.56	11.23	3.75	6.70	5.76	22.22	6.77	10.32	3.85	8.03
Industrial Production	5.35	6.68	0.55	3.17	0.94	5.83	4.11	8.42	2.62	2.61	1.48	2.89
CPI Inflation	2.41	0.46	0.80	0.58	0.35	1.43	0.83	1.59	1.90	0.61	0.49	1.48
Core CPI Inflation	0.86	0.48	0.46	0.43	0.28	0.34	3.77	2.07	0.57	0.15	0.24	0.46
PCE Price Inflation	2.10	0.55	0.60	0.23	0.36	1.07	1.69	1.21	1.63	0.50	0.70	1.02
Core PCE Inflation	1.26	0.94	0.30	0.16	0.26	0.59	3.06	1.12	0.74	0.21	0.53	0.29
Nonfarm Employment	1.11	1.76	0.24	0.87	0.11	0.81	1.38	1.84	0.70	0.43	0.24	0.43
Unemployment Rate	0.32	0.08	0.15	0.10	0.10	0.44	0.36	0.67	0.06	0.13	0.12	0.15
Consumer Confidence	#N/A	4.15	2.09	1.37	5.41	9.66	#N/A	15.63	4.35	7.34	2.78	6.57
10-Year Treasury Yield	0.23	0.35	0.30	0.71	0.39	0.15	0.53	1.18	0.38	0.40	0.24	0.25
Real Federal Funds Rate	0.74	0.88	0.56	0.43	0.49	0.51	1.04	1.20	0.47	0.16	0.30	0.33
Real Spot WTI Price ($)	0.21	0.51	1.94	0.80	0.96	3.06	8.50	10.05	1.06	1.99	3.28	2.46

NOTE: Standard deviations of the unemployment rate, consumer confidence, the 10-year Treasury yield, the real federal funds rate, and the real oil price are based on levels. Standard deviations of all other series are based on compounded annual rates of growth.

Episode 1: 1973/Q3 (T=0)
Episode 2: 1979/Q2 (T=0)
Episode 3: 1989/Q1 (T=0)
Episode 4: 1995/Q4 (T=0)
Episode 5: 1999/Q2 (T=0)
Episode 6: 2002/Q3 (T=0)

Table 3
Predicting Real GDP Growth (Y_t) Using Lagged Real GDP Growth,
Oil Prices (X_t) and the Chicago Fed's National Activity Index (Z_t)
Sample period is 1970.1 to 2007.4
(Standard Errors in Parentheses)

	(1)	(2)	(3)	(4)
Constant	1.90 ***	2.91 ***	4.84 ***	5.33 ***
	(0.45)	(0.52)	(0.45)	(0.48)
Y_{t-1}	0.22 ***	0.14	-0.26 ***	-0.31 ***
	(0.08)	(0.08)	(0.08)	(0.08)
Y_{t-2}	0.14 *	0.08	-0.13 **	-0.15 **
	(0.08)	(0.08)	(0.06)	(0.06)
Y_{t-3}	0.00	-0.01	-0.17 ***	-0.16 ***
	(0.08)	(0.08)	(0.06)	(0.06)
Y_{t-4}	0.01	0.00	-0.06	-0.06
	(0.08)	(0.08)	(0.06)	(0.06)
X_{t-1}		-0.04		-0.04 **
		(0.03)		(0.02)
X_{t-2}		-0.07 **		-0.06 ***
		(0.03)		(0.02)
X_{t-3}		-0.03		0.01
		(0.03)		(0.02)
X_{t-4}		-0.05 *		0.00
		(0.03)		(0.02)
Z_t			2.62 ***	2.48 ***
			(0.28)	(0.29)
Z_{t-1}			1.33 ***	1.53 ***
			(0.40)	(0.40)
Adj. R^2	0.06	0.12	0.55	0.58
D.W.	2.00	2.00	1.99	2.03

NOTE: ***, **, * denote significance at the 1, 5, and 10 percent level.

Table 4
Do Changes in Oil Prices Matter for the Real Economy?
Subset F-Test on lags of Hamilton's 12-Quarter Oil Shock Variable

	1970.1 - 2007.4			1970.1 - 1982.4			1983.1 - 1994.4			1995.1 - 2007:4		
	Sum of Coefficients	*F* -statistic	*p* -value	Sum of Coefficients	*F* -statistic	*p* -value	Sum of Coefficients	*F* -statistic	*p* -value	Sum of Coefficients	*F* -statistic	*p* -value
Expenditures												
Real GDP	-0.0917	872.4 ***	0.0000	-0.0603	269.5 ***	0.0000	-0.0047	193.4 ***	0.0000	-0.1327	224.8 ***	0.0000
PCE	-0.0668	941.6 ***	0.0000	-0.0287	344.6 ***	0.0000	-0.1869	133.0 ***	0.0000	-0.1074	263.8 ***	0.0000
Fixed Investment	-0.1375	146.2 ***	0.0000	-0.1673	71.0 ***	0.0000	0.0301	9.0 ***	0.0048	-0.2649	30.1 ***	0.0000
Business Investment	-0.0186	97.7 ***	0.0000	-0.0080	54.1 ***	0.0000	0.1368	4.5 **	0.0401	-0.1686	22.9 ***	0.0000
Structures	-0.0106	34.5 ***	0.0000	-0.0452	28.9 ***	0.0000	-0.2054	3.4 *	0.0720	0.0601	4.1 **	0.0493
Equipment & Software	-0.0322	79.0 ***	0.0000	-0.0170	55.3 ***	0.0000	0.3017	2.0	0.1615	-0.3281	23.1 ***	0.0000
Residential	-0.2304	38.3 ***	0.0000	-0.3473	12.2 ***	0.0012	-0.1667	8.0 ***	0.0076	-0.1540	11.6 ***	0.0015
Exports	0.2732	20.5 ***	0.0000	0.3967	4.3 **	0.0448	0.3828	3.5 *	0.0709	0.0412	8.9 ***	0.0048
Imports	-0.2704	54.7 ***	0.0000	-0.3738	17.9 ***	0.0001	0.4623	1.7	0.2022	-0.4657	43.4 ***	0.0000
Prices												
CPI	0.0386	1028.7 ***	0.0000	0.0405	459.4 ***	0.0000	0.0227	121.9 ***	0.0000	0.1830	97.4 ***	0.0000
Core CPI	0.0887	1868.2 ***	0.0000	0.1166	455.7 ***	0.0000	0.0231	630.3 ***	0.0000	0.0019	2338.6 ***	0.0000
PCE Price Index	0.0334	1556.6 ***	0.0000	0.0555	458.1 ***	0.0000	-0.0383	271.4 ***	0.0000	0.0721	184.6 ***	0.0000
Core PCE Price Index	0.0653	3170.7 ***	0.0000	0.0934	920.4 ***	0.0000	-0.0169	414.1 ***	0.0000	0.0150	1720.4 ***	0.0000

NOTE: GDP components are measured in $2000 chain-weighted dollars. The regressions are of the form:

$$\Delta \ln(y_t) = \alpha_t + \sum_{i=1}^{4} [\beta_i \Delta \ln(y_{t-i}) + \delta_i \Delta \ln(x_{t-i})] + \sum_{i=0}^{1} \gamma_i z_{t-i} + e_t$$

where z_t is the Chicago Fed's National Activity Index, x_t is domestic crude petroleum production transformed according to Hamilton (2003), and y_t are the dependent variables above. For the reported *p* -values, ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Table 5
Evaluating Forecasts With and Without Oil Price Increases
Root Mean Square Forecast Errors in Percent

	Base	+PZTEX	+PPI
Expenditures			
Real GDP	1.60	**1.56**	1.57
PCE	1.55	**1.41**	1.47
Fixed Investment	5.21	5.28	5.38
Business Investment	5.60	5.69	5.94
Structures	8.83	8.86	9.45
Equipment & Software	5.98	6.00	6.05
Residential	9.27	9.48	10.03
Exports	7.13	7.35	7.30
Imports	5.31	**4.69**	4.96
Prices	1.77	1.76	1.79
CPI	2.03	2.01	2.03
Core CPI	0.63	0.81	0.91
PCE Price Index	1.47	1.46	1.48
Core PCE Price Index	0.51	0.61	0.59

NOTE: The base forecast is an AR(4) model augmented with the contemporaneous and first lag of the CFNAI; this is regression (3) from Table 3. The alternative models are augmented with either the spot price of West Texas Intermediate (WTI) or the PPI for domestic crude petroleum production. Both oil prices are transformed according to Hamilton (2003). The augmented model is regression (4) from Table 3. The base and alternative models are estimated for the period 1970:Q1 to 2001:Q4. Then, one step-ahead pseudo forecasts are estimated for 2002:Q1 to 2007:Q4. Forecast errors in bold indicate that the forecast errors from augmented model are significantly different from the base model according to the Clark-McCracken test.

Table 6
Forecasts of Real Output and Expenditure Growth and Price Inflation
Averages of Quarterly Data at Annual Rates

Indicator	2007	2008	2009
Real GDP	*(Actual)*		
SPF	2.2	1.9	NA
Baseline		2.8	3.3
Baseline plus $100 Oil		2.0	3.6
Baseline plus $150 Oil		1.4	2.2
Real PCE			
SPF	2.9	1.9	NA
Baseline		2.8	3.2
Baseline plus $100 Oil		1.9	3.3
Baseline plus $150 Oil		1.3	2.1
Business Fixed Investment			
SPF	4.8	2.1	NA
Baseline		6.3	5.3
Baseline plus $100 Oil		3.3	5.2
Baseline plus $150 Oil		2.4	0.6
PCE Price Index			
SPF	2.6	2.5	NA
Baseline		3.1	2.8
Baseline plus $100 Oil		2.7	2.6
Baseline plus $150 Oil		2.8	2.3
Core PCE Price Index			
SPF	2.1	2.1	NA
Baseline		2.1	2.2
Baseline plus $100 Oil		2.1	2.1
Baseline plus $150 Oil		2.0	2.0

NOTE: The baseline forecast is an AR(4) plus the CFNAI. The forecast horizon for the Survey of Professional Forecasters is 2008:Q1 to 2009:Q1.